A. System Data Addendum

A FEA System Data Manual document was provided by FEA which included data for generation, transmission and distribution. The FEA manual is not included with this report.

However, KEMA recommends that FEA add the following data into the existing FEA System Data Manual. The following data includes summaries for distribution transformers, HV conductors and LV conductors. All summaries are for the VLIS except those specifically identified.

Distribution Transformer Summaries

Connected Capacity kVA	Central		Western		Sum		No Load Loss	Load Loss	Total Loss
VLIS	**count**	**kVA**	**count**	**kVA**	**count**	**kVA**	**kW**	**kW**	**kW**
Dist. Txfr Kiosk	431	209,580	194	102,970	625	312,550	421	204	626
Dist. Txfr Pole	1,167	63,709	1,815	85,827	2,982	149,536	304	143	447
Sum	1,598	273,289	2,009	188,797	3,607	**462,086**	**725**	**348**	**1073**

Note: count of transformers was adjusted by removing those without a Txx ID or with zero kVA capacity. As a result, total connected kVA is also adjusted by removing the transformer capacity for those transformers removed.

Distribution Transformer Summary Northern Region

Connected Capacity kVA	Northern
Pole Mounted Transformer AC	10,108

Pole Mount Distribution Transformer Detail

kVA size	count	sum of capacity	No Load Loss (W)	Load Loss (W)	No Load Loss (%)	Load Loss (%) @100% load
1	1	1			0.25%	1.75%
2	80	160			0.25%	1.75%
4	1	4			0.25%	1.75%
5	480	2,400			0.25%	1.75%
7.5	13	98			0.25%	1.75%
10	55	550			0.25%	1.75%
12	1	12			0.25%	1.75%
15	129	1,935			0.25%	1.75%
16	791	12,656			0.25%	1.75%
20	1	20			0.25%	1.75%
25	60	1,500			0.25%	1.75%
30	592	17,760			0.25%	1.75%
50	198	9,900	**125**	**875**	0.25%	1.75%
75	9	675	168	1,175	interpolation	
100	210	21,000	**210**	**1,475**		
150	22	3,300	285	1,913	interpolation	
160	0	0	**300**	**2,000**		
200	241	48,200	356	2,333	interpolation	
250	1	250	**425**	**2,750**		
300	96	28,800	498	3,135	interpolation	
315	1	315	**520**	**3,250**		

Notes: Average percent for no load loss and load loss for transformers below 50kVA are assumed same percentage as 50kVA. No load loss and load loss data for transformers at or above 50kVA are from literature[1].

Linear interpolation or extrapolation of the typical loss data are calculated for non-typical kVA size of distribution transformers in FEA system.

[1] EN 50464-1, 2007 Three-phase oil-immersed distribution transformers 50 Hz, from 50 kVA to 2500 kVA with highest voltage for equipment not exceeding 36 kV - Part 1: General requirements

Kiosk Distribution Transformer Detail

kVA size	count	sum of capacity	No Load Loss (W)	Load Loss (W)	Note
10	1	10	57	395	extrapolation
50	4	200	**125**	**875**	
100	19	1,900	**210**	**1,475**	
150	15	2,250	285	1,913	interpolation
160	0	0	**300**	**2,000**	
200	55	11,000	356	2,333	interpolation
250	2	500	**425**	**2,750**	
300	168	50,400	498	3,135	interpolation
315	2	630	**520**	**3,250**	
500	180	90,000	**720**	**4,600**	
630	0	0	**800**	**5,600**	
750	116	87,000	892	6,588	interpolation
800	11	8,800	**930**	**7,000**	
1000	47	47,000	**1,100**	**9,000**	
1250	0	0	**1,350**	**11,000**	
1430	2	2,860	1,530	12,543	interpolation
1500	1	1,500	1,600	13,143	interpolation
1600	0	0	**1,700**	**14,000**	
2000	0	0	**2,100**	**18,000**	
2500	0	0	**2,500**	**22,000**	
3500	1	3,500	3,300	30,000	extrapolation
5000	1	5,000	4,500	42,000	extrapolation

** Linear interpolation or extrapolation of the typical loss data are calculated for none-typical kVA size of distribution transformers in FEA system.

Feeder Conductor Summaries

The unit of conductor length in original FEA data was not specified. Length in the summary below is in original unit. Typical conductor type is identified as most popular conductor type used or in mid range of all types identified if possible and used for loss estimation. Ohm/km and rating Amps for typical conductor types are from EasyPower's standard component library.

HV Feeder Conductors Summary

underground high voltage feeder						
region	**nominal voltage (kV)**	**count**	**length (m)**	**typical conductor type assumed**	**ohm/km**	**rating (A)**
central	**11**	547	201,484	95mm2 (3C) Al	0.35871	230
	6.6	83	40,396	70mm2 (3C) Cu	0.299591	250
	sum	630	241,880			
western	**11**	191	65,167	95mm2 (3C) Al	0.35871	230
	6.35	0	0	-	-	-
	sum	191	65,167			
total		821	307,020			

overhead high voltage feeder						
region	**nominal voltage (kV)**	**count**	**length (m)**	**typical conductor type assumed**	**ohm/km**	**rating (A)**
central	**11**	12,582	850,766	4 x 7/3.75 AAAC HELIUM	0.390937	307
	6.6	37	1,246	4 x 7/3.75 AAAC HELIUM	0.390937	307
	sum	12,619	852,012			
western	**11**	19,310	1,369,405	3 x 6/1/3.66 ACSR MINK	0.463337	252
	6.35	203	38,529	6/1/2.36 ACSR GOPHER	1.11513	151
	sum	19,513	1,407,934			
total		32,132	2,259,946			

overall high voltage feeder						
region	**nominal voltage (kV)**	**count**	**length (m)**	**average section length (m)**	**average R/km**	**count**
central	**11**	13,129	1052250	80.15	0.38477	49
	6.6	120	41615	346.79	0.30233	8
	sum	13,249	1093865			57
western	**11**	19,501	1434572	73.56	0.45858	50
	6.35	203	38529	189.80	1.11513	1
	sum	19,704	1473101			51
total		32,953	2566966			108

VLIS	total number of feeder	total number of feeder section	total feeder length (Meter)	average number of section per feeder	average section length (meter)	average R/km
11kv	99	32630	2486822	330	76	0.42735
6.6kv	8	120	41615	15	347	0.30233
6.35kv	1	203	38529	203	190	1.11513
sum	108	32953	2566966			

LV Conductor Summary

VLIS	underground				
central	**count**	**length (m)**	**typical conductor type**	**Ohm/km**	**rating (A)**
240	56	2,993	50mm2 (4C) Cu	0.432619	150
415	807	89,685	185mm2 (4C) Cu	0.110782	290
others	0	0			
sum	863	92,678			
western					
240	4	240	50mm2 (4C) Cu	0.432619	150
415	137	11,303	185mm2 (4C) Cu	0.110782	290
others	7	451			
sum	148	11,994			
total	1,011	104,672			

VLIS	overhead				
central	count	length (m)	typical conductor type	Ohm/km (ETAP)	rating (A)
240	10,473	610,776	2 x 7/3.75 AAAC HELIUM	0.390937	307
415	9,316	385,964	4 x 7/3.75 AAAC HELIUM	0.390937	307
others	2	67			
sum	19,791	996,807			
western					
240	27,860	1,932,693	2 x 7/3.75 AAAC HELIUM	0.390937	307
415	5,958	238,337	4 x 7/3.75 AAAC HELIUM	0.390937	307
others	5	304			
sum	33,823	2,171,334			
total	53,614	3,168,141			

VLIS	overall	
Central	count	length (m)
240	10,529	613,769
415	10,123	475,649
Others	2	67
Sum	20,654	1,089,485
Western		
240	27,864	1,932,933
415	6,095	249,640
others	12	755
sum	33,971	2,183,328
total	54,625	3,272,813

LV feeder	overall		
	count	length (m)	average section length (m)
240	38,393	2,546,702	66.33
415	16,218	725,289	44.72

B. Formulas Used for Loss Calculations

4.2.1

Annual Transmission and Transformer Loss Formulas

With peak transmission line losses provided as input, annual transmission energy losses are calculated according to the following formula:

$$Transmission\ line\ and\ cable\ losses\ MWh = LineandCableLossMW * SystemLossFactor * 8760$$

Similarly, Power transformer energy losses are calculated by the following formula:

$$Transformer\ annual\ energy\ loss\ MWh = (NoLoadLossMW + LoadLossMW * LossFactor) * 8760$$

4.2.2

Annual Feeder Loss Formulas

With peak feeder losses provided in MW, annual energy losses in MWh were calculated by the following formula for each feeder:

$$Feeder\ annual\ energy\ loss\ MWh = FeederLossMW * FeederLossFactor * 8760$$

Energy losses in MWh through the secondary system were estimated with the following formula:

$$Secondary\ annual\ energy\ loss\ MWh = SecondaryLossMW * LossFactor * 8760$$

Factors

- Utilization Factor (UF)

$$UF = \frac{PeakkWLoad}{TotalConnectedkVA}$$

- Connected kVA

  Equals sum of installed distribution transformer KVA connected to the feeder.

- Load Factor (LDF)

$$LDF = \frac{kWh\,Load \quad During \quad Specified \quad Time\,Period}{(HoursInTimeperiod) * (PeakkWLoad)}$$

- Loss Factor (LSF)

$$LSF = \frac{kWh\,Loss \quad During \quad Specified \quad Time\,Period}{(HoursInTimeperiod) * (PeakkWLoss)}$$

The relationship between LSF and LDF is

$$LSF = C * LDF + (1 - C) * LDF^2$$

Where C varies from 0.15~0.3[2], C=0.2 is applied to estimate losses for FEA.

[2] Electric Power Distribution System Engineering, by Turan Gonen